Evaluating How Students would use a Collaborative Linked Learning Space

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ABSTRACT

Personal interaction with learning materials, (re-)arranging learning resources in a semantically meaningful way is important for comprehension and personal knowledge construction. Current learning systems only enable learners to add simple digital ink or text notes. How would users work with a system for collaboratively augmenting and semantically connecting learning materials with related knowledge resources? This paper presents user studies conducted with both students and educators to elicit users' acceptance, needs and preferences regarding such a learning system.

Categories and Subject Descriptors
K.3.1 [Computer Uses in Education]: Collaborative learning; K.3.2 [Computer and Information Science Education]: Computer science education

General Terms
Design, Experimentation

Keywords
CLLS, Collaborative Learning, Study, User Requirements, Web-based Learning

1. INTRODUCTION

Besides learning materials provided by educators, students create and search for additional learning resources, especially in the World Wide Web [9]. This may be due to various reasons, e.g., if students do not have sufficient prior knowledge to understand the content, or if learning materials do not satisfy individual learning preferences. Due to these reasons, students implicitly augment provided learning material. Augmentations typically include content and statements about the relationship between learning resources. For example, a figure in a PDF exemplifies the content of a slide, or a paragraph of a website contradicts a section of a lecture video.

Active learning with the provided learning materials is an important part of learning processes for transferring provided information to personal knowledge. Iske underlines the importance of the creation of connections, the correlation and meaningful arranging of information and putting knowledge in context [8]. Empirical studies in the field of Adaptive Hypermedia showed the positive effect of link annotation to guide students [6]. By sharing learning resources with other learners and explicitly naming the relationship between the resources

- students can see the relationships between different learning resources as an orientation aid,
- other students can benefit from the augmentations added by fellow students,
- educators can see how students are interacting with the learning material,
- educators can benefit from the students' augmentation, e.g., to see which parts have been difficult to understand, and to find additional or better presentations for their lectures.

In this paper, we present the results of a study examining how students and educators accept and would use a system that enables users to add learning resources to lecture recordings, and to connect various information resources. With this evaluation, we underline theoretical considerations by eliciting the needs and acceptance of both students and educators for such a system. We begin with an overview of related learning systems, introduce a working prototype used for evaluation, explain the evaluation design and present its results. Finally, we provide a summary and an outlook on future work.

2. STATE OF THE ART

Many systems exist for presenting lecture materials and enabling users to add annotations to lecture materials. Systems such as AOF [11], and We-LCoME [5] enable students to replay lecture recordings and to add text notes to slides. eMargo [12] allows students to add text notes to the document margin. Other systems such as Livemotes [10], and WriteOn [4] support the addition of ink notes. Some others
allow students to add both text and digital ink notes, for example Classroom Presenter [1] and CoScribe [13]. MRAS [2] enables users to add audio annotations to lecture videos. CoScribe [13] also links paper-based notes with web-based resources. However, none of these learning systems allow users to explicitly name the semantic relationship between two learning resources in a machine processable form.

This brief overview shows that many systems limit the augmentations of learning materials for both educators and students. Due to these limitations, learners can hardly augment the provided learning material with other learning resources, either found or created by themselves, and describe the semantic relationships between them.

In addition, most of the above systems are desktop applications for Windows. Some support a wider range of operating systems (OSs) as they are Java- or Flash-based, but require additional installations. Those systems also do not support iOS-based devices, such as the iPhone and the iPad. Therefore, learners are restricted to particular OSs and devices when learning. This is a problem for supporting both traditional and mobile learning scenarios.

To sum up, the discussed systems offer no or only limited support for:

• augmenting the provided learning materials for both students and instructors regarding various media types,
• arranging different learning resources and describing the connection between them,
• using a wide range of different devices including laptops, mobile devices, and tablet PCs and computers,
• exchanging learning resources between lecturers and students, and between students.

In the next section, we introduce a system that addresses these problems. We then present studies that examine the acceptance and preferences of both students and educators.

3. THE CLLS SYSTEM

Collaborative Linked Learning Space (CLLS) is a web-based application. Users interact with the system with their browsers. Figure 1 depicts the user interface of CLLS. It shows a lecture recording and the corresponding knowledge graph that is collaboratively created by the users. The lecture replay functionality provides a video of the lecturer (I), a slides overview (II), and the currently selected slide (III). The knowledge graph window (IV) shows a graphical representation of the collaboratively created knowledge graph. Nodes represent learning resources such as slides, PDF documents, or images; edges represent the relationship between the learning resources, e.g., “illustrates”, “contradicts”, or “exemplifies”. Users can for example link a slide with a figure by simply dragging and dropping an image onto the slide or the corresponding node in the knowledge graph. In principle, all information resources can be linked with each other as long as they have a Uniform Resource Identifier (URI). After the user has chosen the label for the relationship, the knowledge graph automatically updates, and the new information is distributed if the added resource is shared.

A more detailed description of the system can be found in [7].

4. USER INTERVIEWS

We conducted interviews with both computer science students and educators. In this section, we describe the goals of the study, the chosen methodology, and the results.

4.1 Goals and methodology

We interviewed students about the following aspects:

• How do students assess the opportunity to link learning resources with other material with a semantical description, and how would they use this?
• How do students assess the usability of CLLS?
• Do students see a benefit in using CLLS and how would they use it?

Educators were interviewed about similar aspects:

• How do educators assess the opportunity to link learning resources with each other and how would they use this?
• Would educators use such a system for their courses?
• Which pros and cons are seen by educators?

The methodology consisted of semi-structured interviews. A common structure with key questions ensured consistency between the interviews. To enhance the interviewees’ understanding and to contextualize the questions, the interviewees had the opportunity to use the system. We also demonstrated the system at the beginning of each interview.

A 5-point Likert scale was used when we asked for an interviewee’s assessment. 1 always meant “strongly disagree” or “not helpful”, and 5 was “strongly agree” or “very helpful”, depending on the type of question. For these questions, the arithmetic mean (AM) and the standard deviation (SD) were computed. One-sample t-tests on the 0.05 level were conducted to investigate whether the ratings were significantly higher or lower than the midpoint of the Likert scale.

The interviews were conducted with two groups: 14 computer science students and 6 computer science lecturers from different research fields including P2P networks, HCI, computer networks, and e-learning. On average, each interview took 1.5 hour. Partly, both groups had the same or similar questions. Due to different foci of the interviews, there were also differences in questions. We also performed an acceptance study with students. They could use the system in advance and were thus familiar with the system. Educators received a demonstration of the system at the beginning of the interviews.
The table below shows the ratings of the helpfulness of semantic descriptions:

<table>
<thead>
<tr>
<th>Semantic description</th>
<th>Students (AM (SD))</th>
<th>Educators (AM (SD))</th>
</tr>
</thead>
<tbody>
<tr>
<td>explains</td>
<td>4.66 (0.36)</td>
<td>4.83 (0.41)</td>
</tr>
<tr>
<td>example for</td>
<td>4.57 (0.76)</td>
<td>5.0 (0.0)</td>
</tr>
<tr>
<td>illustrates</td>
<td>4.14 (1.29)</td>
<td>4.0 (1.10)</td>
</tr>
<tr>
<td>extends</td>
<td>3.86 (1.03)</td>
<td>4.6 (0.55)</td>
</tr>
<tr>
<td>contradicts</td>
<td>3.79 (1.37)</td>
<td>3.4 (0.89)</td>
</tr>
<tr>
<td>agrees</td>
<td>2.59 (1.16)</td>
<td>2.8 (1.5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of learning resource</th>
<th>Students (AM (SD))</th>
<th>Educators (AM (SD))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slide</td>
<td>5.0 (0.0)</td>
<td>5.0 (0.0)</td>
</tr>
<tr>
<td>PDF document</td>
<td>4.93 (0.27)</td>
<td>4.8 (0.45)</td>
</tr>
<tr>
<td>website</td>
<td>4.57 (0.85)</td>
<td>4.8 (0.45)</td>
</tr>
<tr>
<td>figure, diagram</td>
<td>4.3 (0.76)</td>
<td>4.4 (0.89)</td>
</tr>
<tr>
<td>Wikipedia article</td>
<td>4.97 (1.0)</td>
<td>4.6 (0.89)</td>
</tr>
<tr>
<td>forum post</td>
<td>4.64 (1.28)</td>
<td>4.0 (0.41)</td>
</tr>
<tr>
<td>video</td>
<td>3.57 (1.02)</td>
<td>4.8 (0.45)</td>
</tr>
<tr>
<td>word proc. document</td>
<td>3.3 (1.02)</td>
<td>3.2 (1.1)</td>
</tr>
<tr>
<td>pen note (digital pen)</td>
<td>3.36 (1.55)</td>
<td>4.0 (0.71)</td>
</tr>
<tr>
<td>spreadsheet document</td>
<td>3.14 (1.1)</td>
<td>3.2 (1.64)</td>
</tr>
<tr>
<td>chat message</td>
<td>2.79 (1.05)</td>
<td>3.8 (1.1)</td>
</tr>
<tr>
<td>blog post</td>
<td>2.64 (1.01)</td>
<td>4.6 (0.89)</td>
</tr>
</tbody>
</table>

### 4.2 Results

In the following, we present the results of the interviews. Where students and educators had the same question, we compare their answers.

#### 4.2.1 Usability

We tested the usability of the system by conducting a System Usability Scale (SUS) test [3] with the students. SUS scores have a range of 0 to 100. The average score was 88. Thus, students assess the system as very easy to use. This includes an easy navigation through lecture recordings and connecting two learning resources by drag and drop.

#### 4.2.2 Linking learning resources

Students assessed the possibility of linking different learning resources as very helpful (AM=4.71, SD=0.47). They also welcomed the possibility to describe the semantic meaning of such a link (AM=4.57, SD=0.65). Educators agreed with this appraisal. In their opinions, this is very helpful for themselves (AM=4.5, SD=0.84) and students (AM=4.83, SD=0.41). They also thought that a semantic description of the connections between learning resources is helpful for themselves (AM=3.67, SD=0.52) and especially for students in their learning processes (AM=4.20, SD=0.84).

An open question asked both students and educators which semantic descriptions they would use with the system. Both groups suggested “explains”, “example for”, and “illustrates”. Students added “question to” to this list, while educators added structural terms like “prerequisite for”, “before” and “after” referring to the didactical design of a course.

We also provided a list of semantic descriptions and asked both groups to rate each item. Table 1 shows the ratings of both groups. The ratings are quite similar except for “extends”. Educators found this helpful to connect additional learning material for further reading.

Both students and educators were asked in an open question what types of learning resources they would link with each other. Both groups listed “website”, “figure”, “PDF document”, “video”, “animation”, and “source code”. In addition, they rated the importance of presented types of learning resources (see Table 2). Although the ratings of both groups are similar, there are some interesting differences. For example, educators rate Web 2.0 applications like forums, blogs, and Wikipedia higher than students.

Apart from connecting whole documents with each other, it is conceivable to make selections on a more fine-grained level. The interviewees were asked which level they would use. For text documents, the majority would reference to paragraphs as well as single words for linking them with definitions for instance. Timestamps and period of time are important referencing a video. Educators also suggested referencing code snippets.

#### 4.2.3 Sharing learning resources

All interviewed students said they share knowledge resources they have created or found with fellow students. Usually, they use eMail (86%), Web storage (71%), and Instant Messaging software (71%) for the exchange of learning resources. The majority of the interviewees thinks that it is very helpful be able to share learning resources with a system such as CLLS (AM=4.71, SD=0.47). They welcome seeing the semantic relationships added by other learners when those added a learning resource (AM=4.29, SD=0.61). In this way, they can better understand why someone else has connected two learning resources.

Although most students would share learning resources found or created by themselves with fellow students, it is also important for some to be able to make private additions (AM=2.93, SD=1.49), e.g., for notes or private documents. However, the opinions are divided for this question. Some students vote for an open system sharing every linked resource with all other users.

All educators indicated that they often need to pass additional learning material or exercises to students after a lecture. Usually, they do this via eMail, or publish the material on the course website or forum.

All interviewed lectures appreciated the possibility of the system to add additional learning material to the slides of their lectures and to share it with their students. The educators also welcomed that students can augment the provided learning materials. For themselves, they agree that this a good opportunity to recognise problems students have with the learning materials (AM=4.67, SD=0.82), and to see alternative representations of the learning material (AM=4.60, SD=0.89). Thereby they receive feedback to their lectures and can improve their learning materials (AM=4.2, SD=0.84).

#### 4.2.4 Assessing shared learning resources

Students said they think rating learning resources added by other learners and seeing their average rating is very helpful (AM=4.29, SD=0.73), because it could give an orientation which learning resource to access first. Students do not think that there is a benefit to see the rating of a certain person (AM=3.60, SD=0.96) except for the educator. 95% find it helpful to see how the educator has rated certain resources. Educators agreed with this. They also thought
Table 3: Students’ rating of filter criteria

<table>
<thead>
<tr>
<th>Filter criteria</th>
<th>AM</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>learning resources added by the educator</td>
<td>4.00</td>
<td>0.00</td>
</tr>
<tr>
<td>type of learning resource</td>
<td>4.50</td>
<td>0.70</td>
</tr>
<tr>
<td>semantic relationship</td>
<td>4.36</td>
<td>0.74</td>
</tr>
<tr>
<td>average rating</td>
<td>4.14</td>
<td>0.80</td>
</tr>
<tr>
<td>learning resources added by a certain group</td>
<td>3.23</td>
<td>1.05</td>
</tr>
<tr>
<td>period of time</td>
<td>3.00</td>
<td>1.32</td>
</tr>
</tbody>
</table>

that it is important students can see their assessment of a resource (AM=4.83, SD=0.41). However, a student remarked that this could discourage students to add learning resources, because they might be afraid of receiving a bad rating for linked materials. Thus, the possibility to make anonymous posting would lower this barrier to participate. 29% find seeing the average rating of a learning group interesting, 14% the one of a specific student.

4.2.5 Filtering shared learning resources
If learning materials are constantly augmented by both instructors and students, the amount of linked learning resources can be very confusing. Therefore, it is important to be able to set filters to fade out uninteresting items and highlight important ones. We asked students which filter criteria they would use. They prefer filtering for certain semantic relationships, e.g., “show all learning resources that provide an example for this slide”, and for certain types, e.g., “all images”. Students also want to filter learning resources with particular ratings. After this open question, students were asked to rate the filter criteria of a given list (see Table 3). Again, the type and the semantic relation are highly rated, but most important is a filter for the learning resources that were added by the educator. This shows that an educator’s resources have a special position. According to the students, this is because these resources are more important and their correctness is more reliable than resources added by students.

In addition to single filter criteria, a filter may consist of several filters logically connected with each other. Students welcome such a feature (AM=4.36, SD=0.93), because it allows making more detailed queries. Here, most students want to query for a certain type of learning resource that has a certain relationship to another, e.g., “all figures that provide an example for this slide”. They ideally expect a logical combination of all single filters.

4.2.6 Visualization
We wanted to find out how both students and educators assess using a graph to represent resources and their connections (figure 1). Most students believe that this is very helpful (AM=4.0, SD=0.88). The educators shared this view. They assessed a graphical representation of the created knowledge graph to be helpful for both themselves (AM=3.8, SD=0.84) and students (AM=4.0, SD=1.0). However, some interviewees stated that such a representation could be confusing or they would simply prefer a non-visual presentation. Instead, a simple table could be a better representation. Many interviewees also felt that a visual feedback after connecting two learning resources is important as well as being able to see connected learning resources directly on the slide. Some interviewed educators commented that a simple graph as presented is helpful but not sufficient. Such a graphical representation should make it easy to navigate through the graph and to find information. This is especially challenging when many students contribute and a knowledge graph is growing over a long period of time.

An open question asked the interviewees what a good visual-ization would be to see from their point of view. One idea was the combination of different colors and shapes for distinguishing different learning types and their importance. To visualize the rating of a resource, it was suggested to arrange more important resources closer to the corresponding node, or to visualize the different ratings of resource by different color intensities or node sizes. It was also suggested to use clusters in the visualization for an easier navigation.

4.2.7 Archiving linked learning resources
From an educator’s perspective, it can be valuable to be able to save a certain version or state of a knowledge graph including the connected learning resources such as slides, documents, websites, and videos. On average, the educators assessed such an option to be very helpful (AM=4.6, SD=0.55). With this opportunity it is possible to create a final version for the students at the end of a term containing all learning resources. Such a version (maybe edited by the teaching staff) can also be a starting point for students of the lecture in a subsequent term. In addition, saving a knowledge graph could be used for offline usage of CLLS.

Although students did not assess preserving a knowledge graph as high as educators did (AM=3.79, SD=1.19), they saw a benefit in preserving Web resources for removal (100%) and modification (79%). Just under one half of the students want to have a personal final version of the learning resources and their links after a lecture. Instead, the majority would prefer a preservation of the whole resources in combination with filtering mechanisms.

4.2.8 General usage
Both students and educators welcome that the system runs in a Web browser without any plugins, so they do not need to install any extra software. Nevertheless, the majority of the interviewees would like to be able to work both online and offline. Only few students said that they prefer pure online learning. An educator commented that although the system runs on different devices, a different presentation for different device classes would be necessary, due to differences in screen sizes and interaction techniques between devices.

Most students also like the flexible user interface that allows them to arrange it as they like (AM=4.57, SD=0.51). However, almost all students request the presence of layout presets (AM=3.57, SD=1.5).

All interviewed students own a laptop, but would use the system on different devices, especially with laptops (100%), tablet computers such as the iPad (93%), and PCs (70%). Many students said they would like to access CLLS with a smartphone, but are concerned about the small screen size.

In a final question, we asked the interview participants to share their views on the system regarding benefits and disadvantages, and in comparison to known learning systems. The majority assess the integration of different learning resources as the greatest benefit. Students welcome that, in contrast to LMSs and lecture recording players, they can actively link learning resources by themselves directly with the...
learning materials. They like the easy usability of the system and the sharing opportunities of information resources. However, some students saw a potential danger of low quality resources added by some students. In summary, the students felt that they would learn effectively with such a system (AM=4.14, SD=0.77).

The overall feedback from all educators was also very positive. They stated that such a system could support students in active learning with learning materials, especially due to the possibility to add learning resources and to make semantic connections between them. For some educators this was a big advantage in comparison with LMSs. They also saw a benefit that students have an integrated view of learning materials and social presence of co-learners.

5. SUMMARY AND OUTLOOK

In this paper, we have presented user studies regarding a system that facilitates users to collaboratively link learning resources with each other and to describe these relationships. In order to elicit the acceptance and preferences of both students and educators for such a system we have built a working prototype and conducted interviews with users. The interview results showed that both groups say a system like CLLS could effectively support students in their learning processes. Students welcome the easy usability of the system. They especially welcome the opportunity to connect information resources, which they have created or found in the WWW, with the provided lecture materials. They also support the exchange of information resources with fellow students, because they could benefit from the learning resources added by others and vice versa. Students appreciate the integrative character of CLLS collecting all learning resources in one place. The interviewed educators underlined these statements. Each educator would use such a system for their lectures. Due to student augmentations, educators receive feedback to improve their teaching materials.

Besides the advantages of the system, new requirements and concerns emerged during the interviews. Although a browser-based system has advantages such as a wide support of different devices, the majority of students demands both an online and offline use. Another challenge is the visualization and interaction with a huge knowledge graph collaboratively created by many users over a long period of time.

The reactions of both students and educators have been very motivating for us. The small deviation of the answers makes it unlikely that the positive reactions are partially due to a wish to make us happy. We plan to conduct a long term study to examine how the system is used over a long period of time by both educators and students with a particular focus on collaborative learning activities. We also plan to integrate collaboration tools like chat, discussion forum, and social networks in order to facilitate interaction and to support the semantic connection of such tools. Furthermore, we plan to perform user studies with different visualizations of the knowledge graph, and interactions techniques. Whereas computer science lectures are often slide-based, other subjects like philosophy are more text-based. Thus, we want to support users to link various types of information resources with fine-grained selectors for different types of media.

6. REFERENCES


